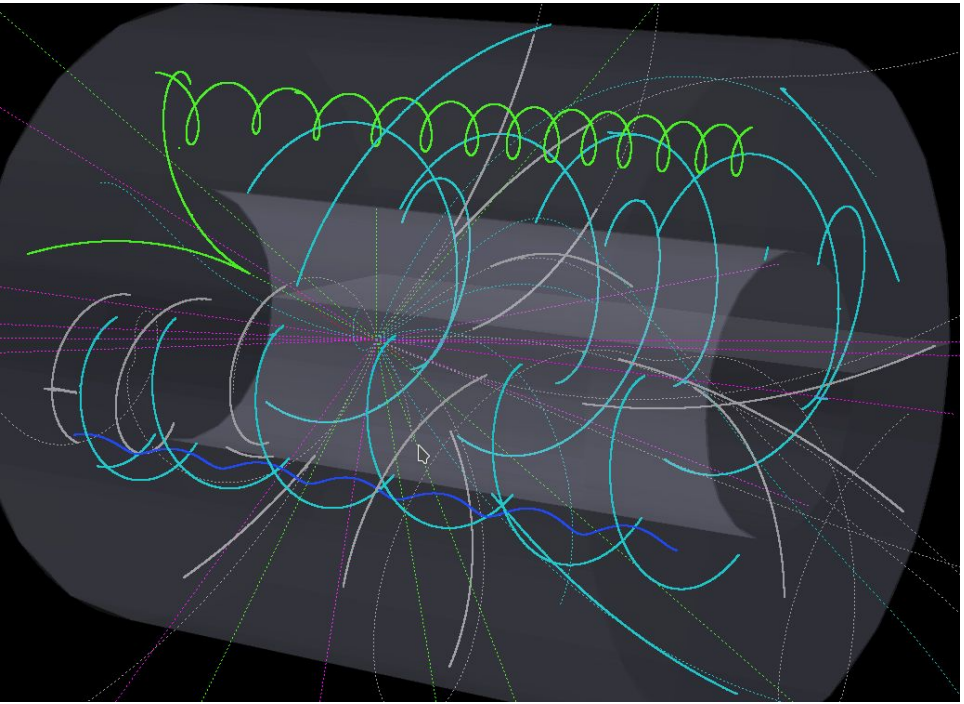

A tracking TPC for Belle II upgrade

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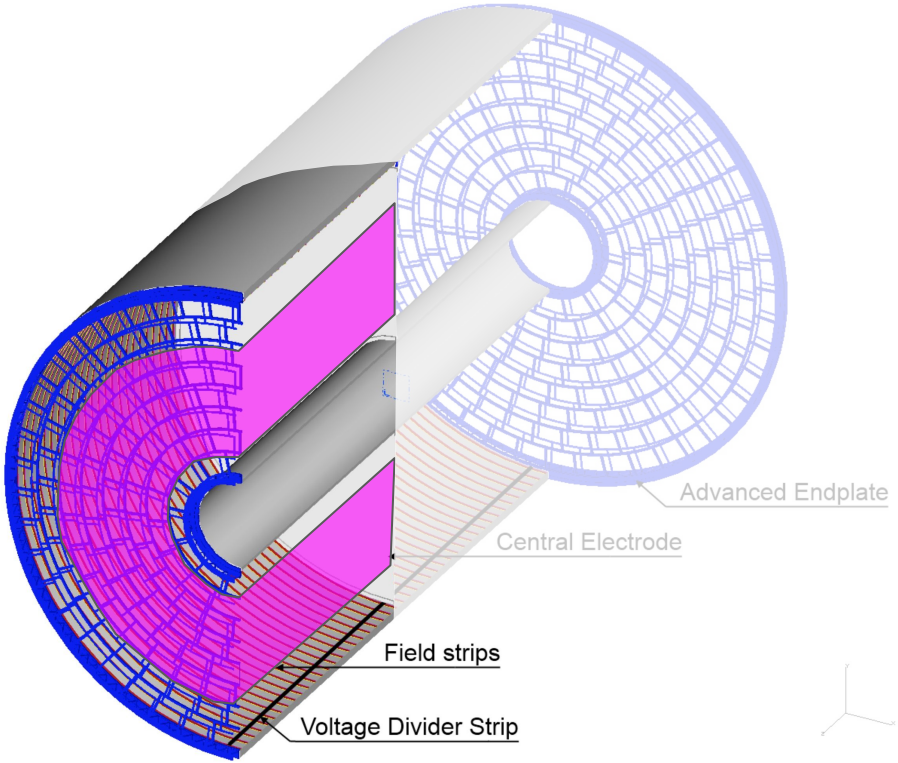
Overview

A proof-of-concept project

- Can a **tracking TPC** work for Belle in the future? (2030+ SuperKEKB luminosity upgrade)
- **Fine 3D segmentation** in principle is far more tolerant of high rates/high backgrounds

This project: demonstrate **proof-of-concept** for a tracking TPC in Belle II. Use **LCTPC** as a starting point with **Belle II** simulation.



Status

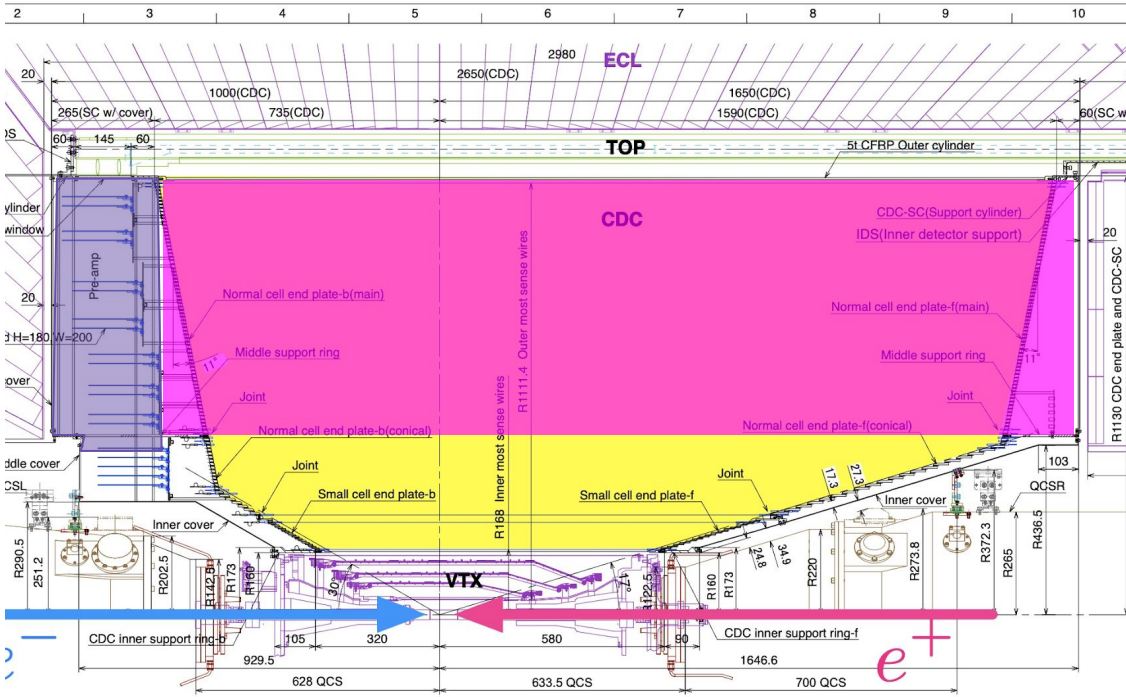
Working towards a white paper

- We are a small team of **Belle II** and **LCTPC** collaborators
- We have been working for ~4 months:
  - One masters thesis in progress
  - One PhD thesis portion in progress
  - Others contributing less formally
- Working towards a White Paper for summer 2021

Geometry

Largely inflexible

- Can't put readout on FWD side (asymmetric collider-->PID detector in FWD region is beyond tracking volume)
- Inner tracking volume has strange shape, not appropriate for TPC
  - Abandon to expanded silicon



Fill remaining volume with **single drift volume** and **read out** on BWD end

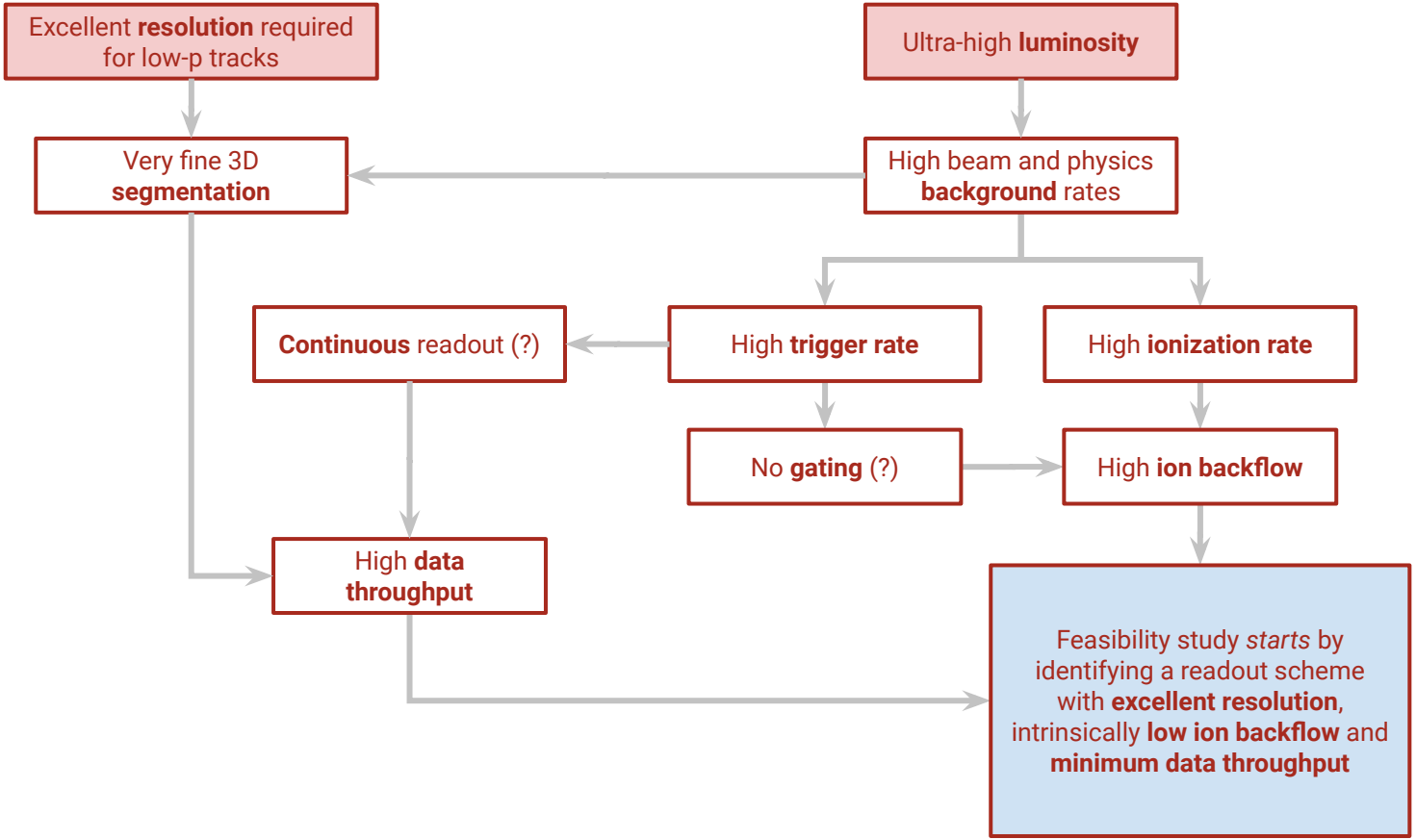
Primary technical concerns

"This won't work at Belle because…"

- TPC can't provide a **trigger**
- **Event rate is too high**
- No **dE/dx** for low-p_T tracks
- …

Our first goal is to demonstrate **potential solutions** to these problems in simulation

(some) Readout considerations



GridPix: a starting point

Pixel chip with integrated MICROMEGAS

Excellent resolution:

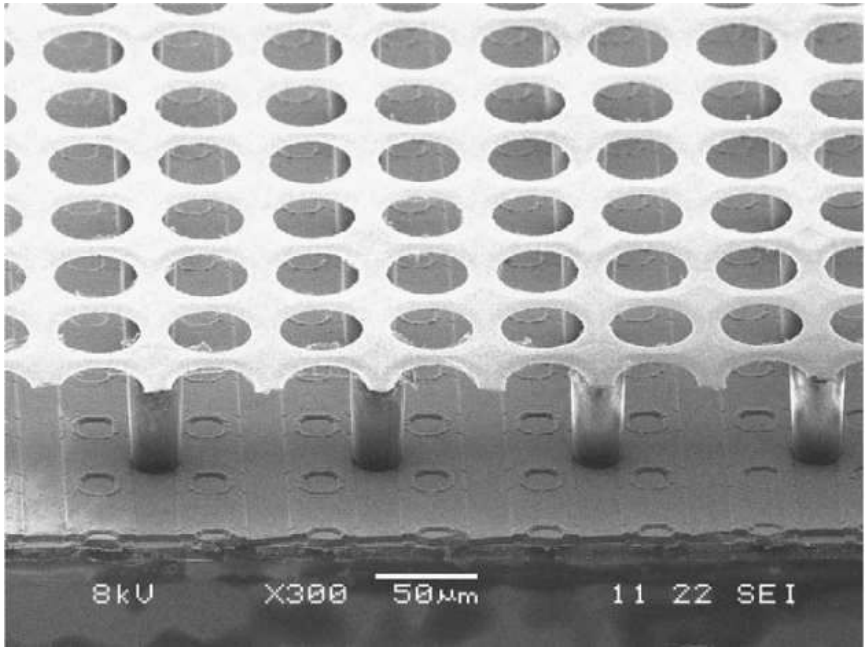
- 50x50x pixels

Low throughput:

- **Single-electron** detection
- Can use **binary readout**

Low intrinsic ion backflow:

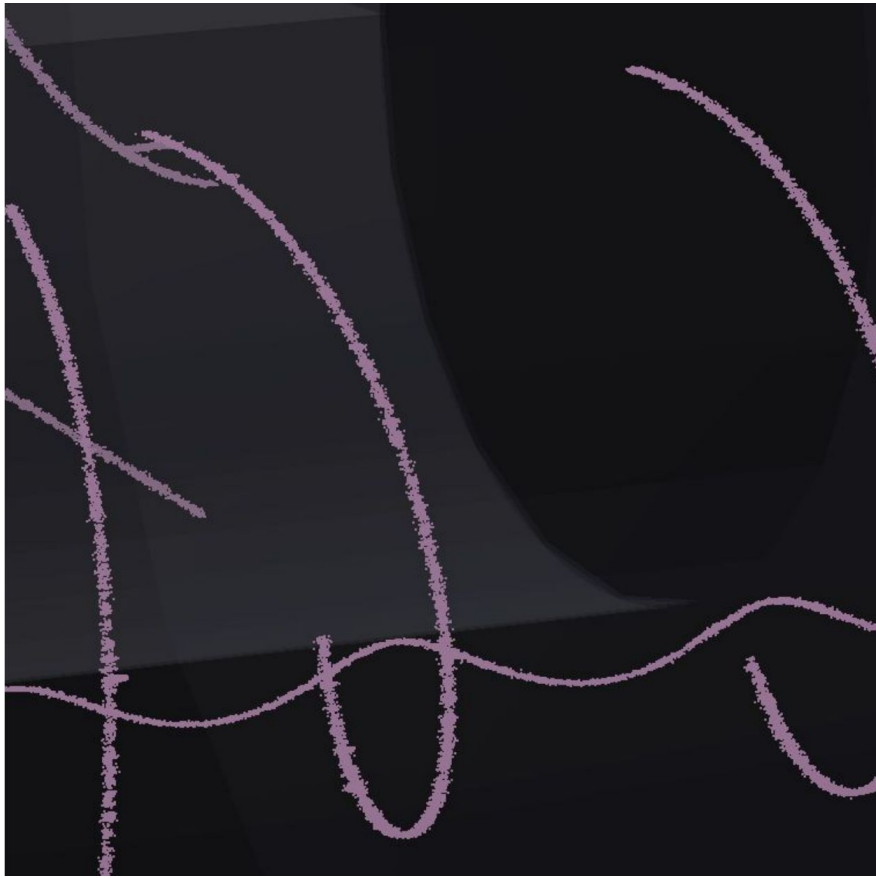
- (LCTPC): Ion backflow as low as **1 ion per primary electron,** with >90% efficiency



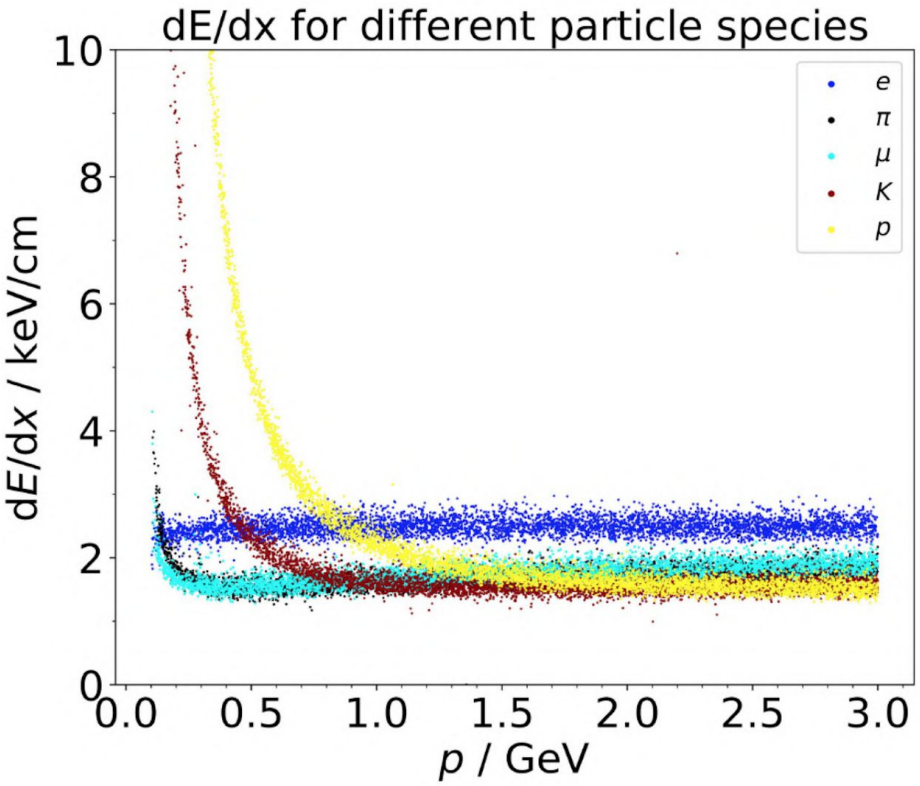
Simulation

Where we are right now

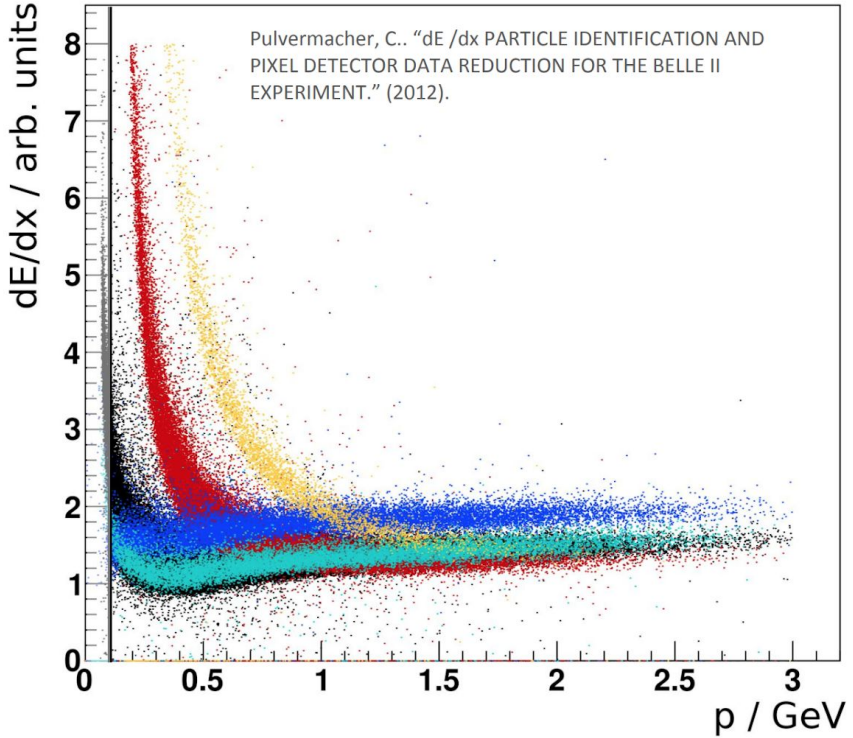
- Currently a combination of Belle 2 simulation and standalone code
- Currently implemented:
  - One electron → one hit (approximating InGrid detector)
  - Pixel chip, binary readout (50x50x50um^3 voxels)
  - **T2K gas** with simulated **diffusion** and ionization properties
- Currently **not** implemented:
  - Field cage, drift field, field uniformity, etc.



Simulation demo: dE/dx

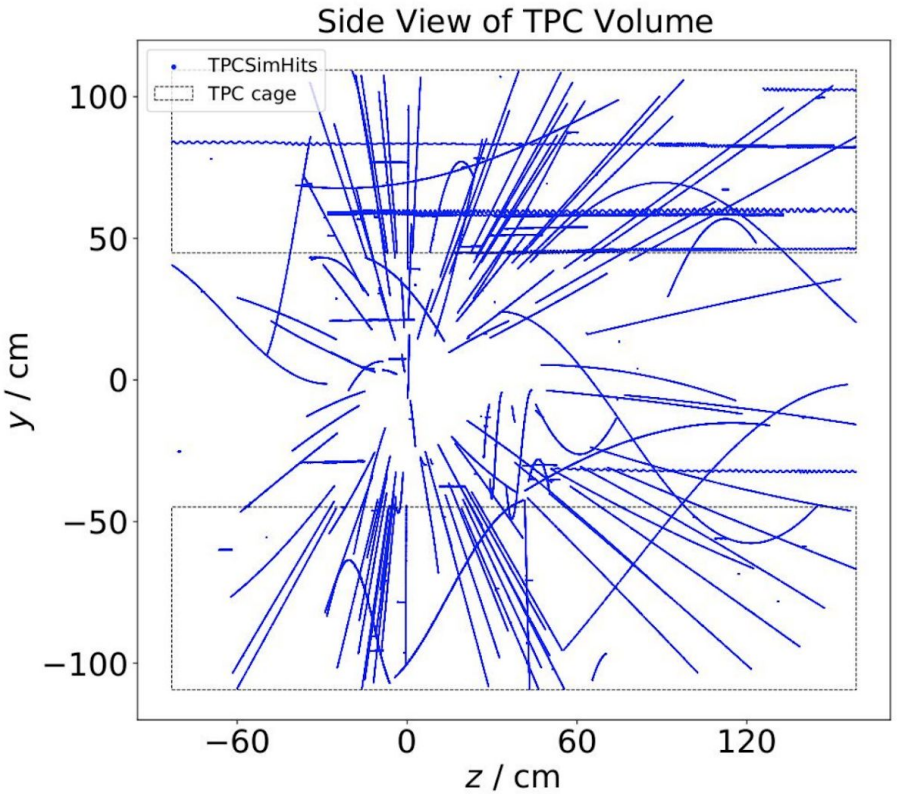


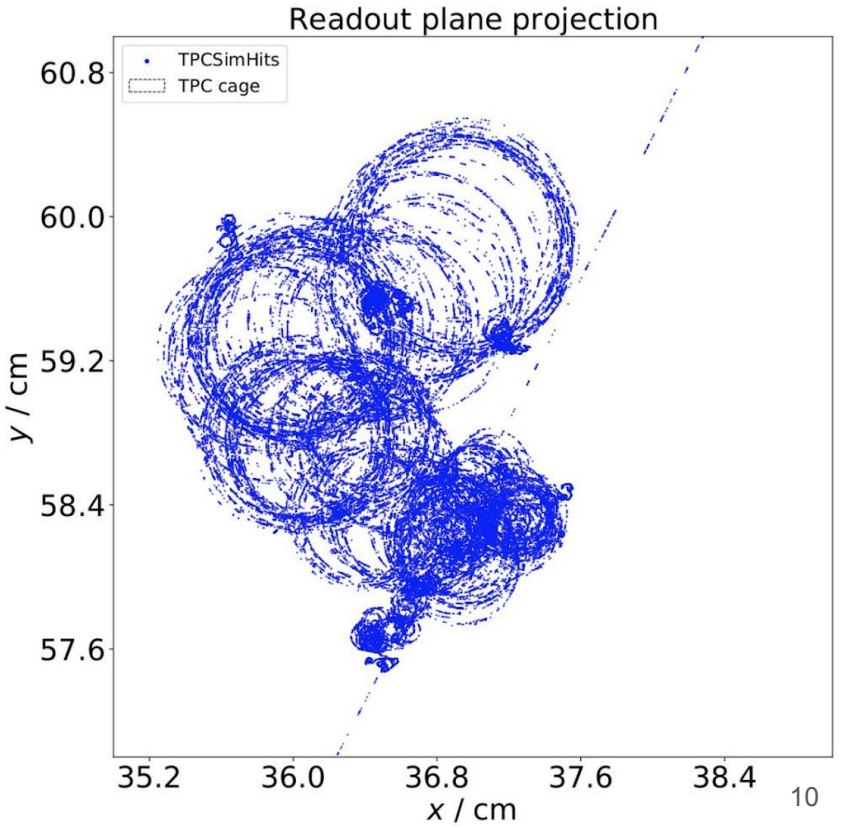
particles do not reach the TPC due to B-field

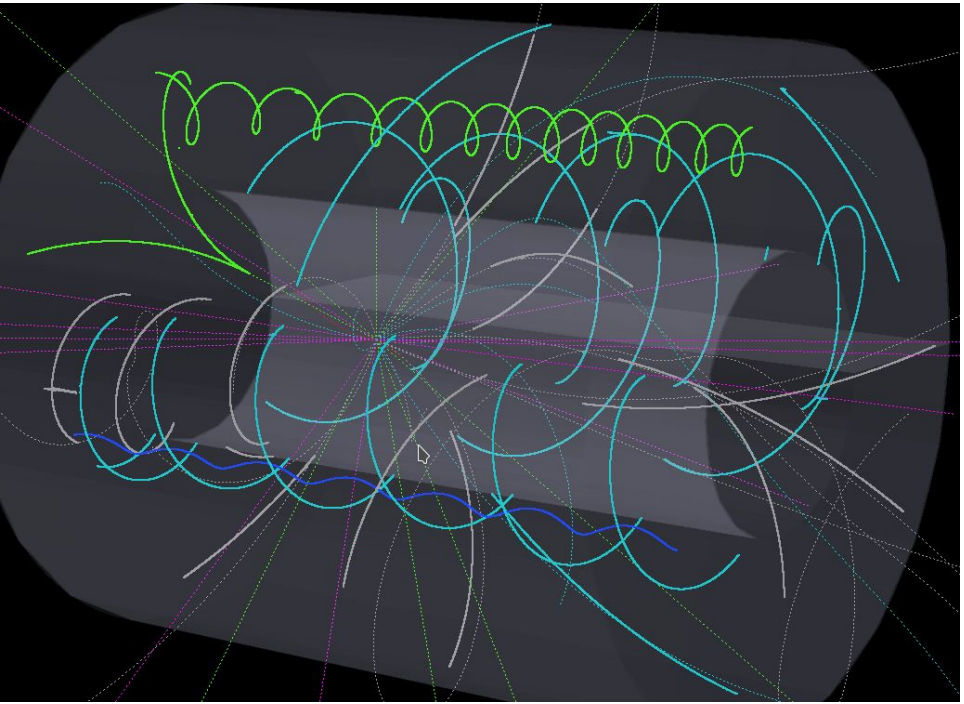


(b) CDC

Simulation demo: micro-curlers (100 pions)





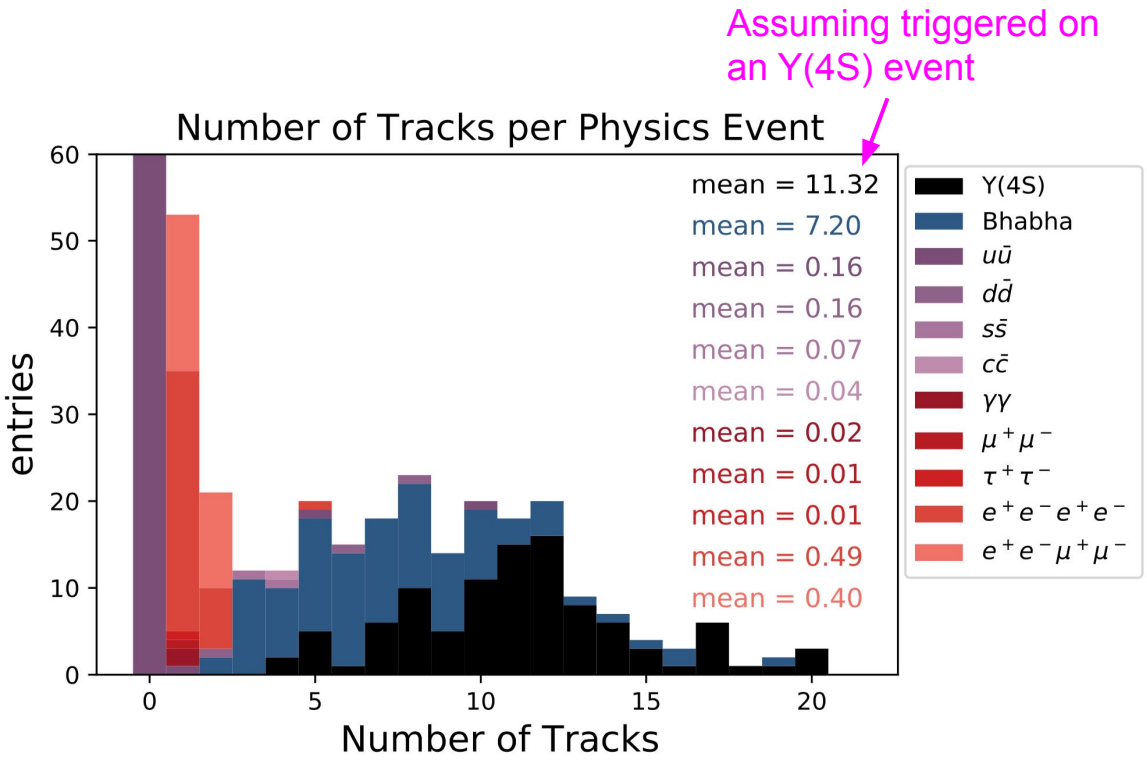


Early work addressing the technical concerns

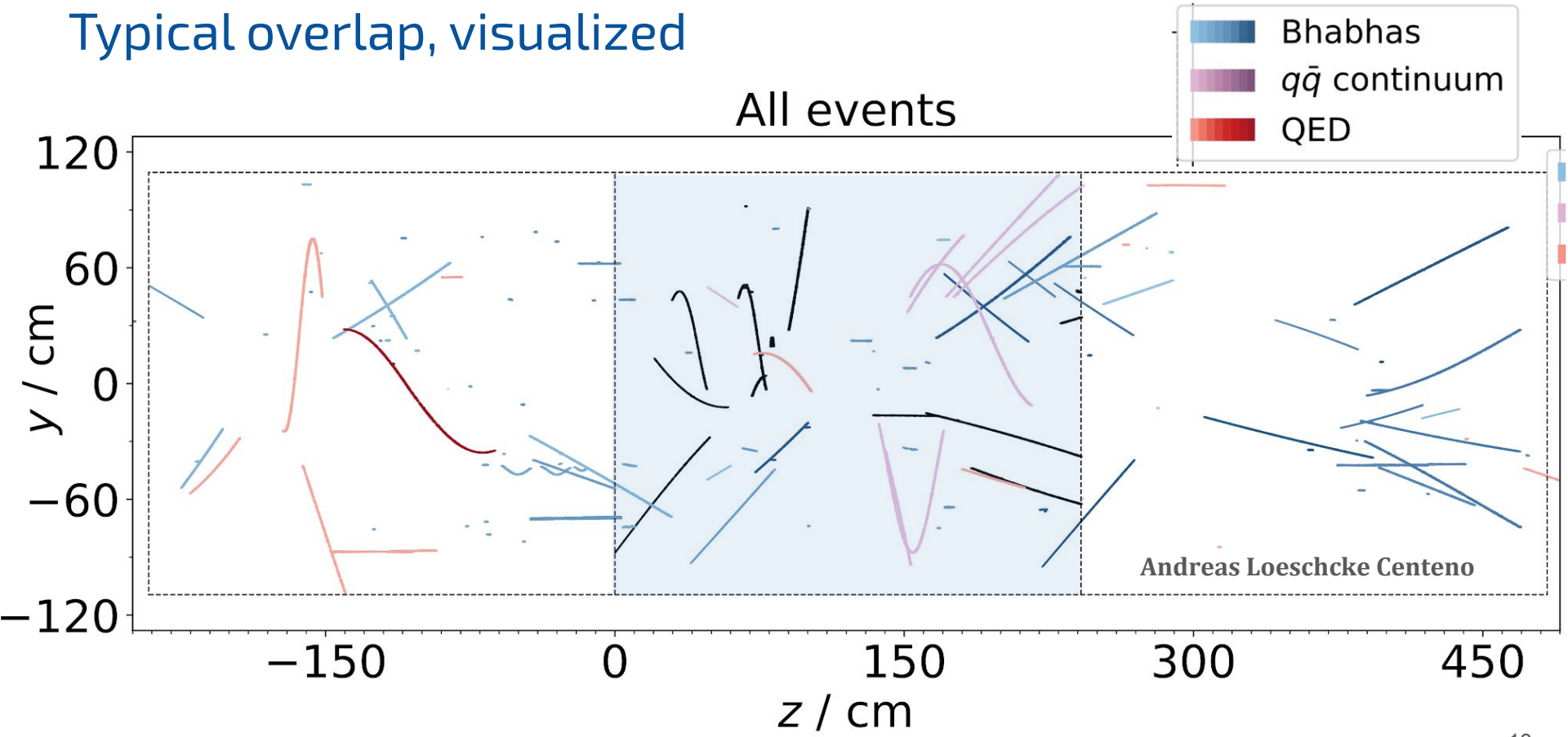
Event pileup

Per **30us drift volume**

- *Full Belle II luminosity*
- Bhabha dominated (but these should be relatively easy to identify and remove)
- We have **many tools** (IP pointing, diffusion, etc.) to identify and remove overlaid physics
- Overall this isn't a problem… and furthermore shows that **gating may not be impossible** (depending on target luminosity)



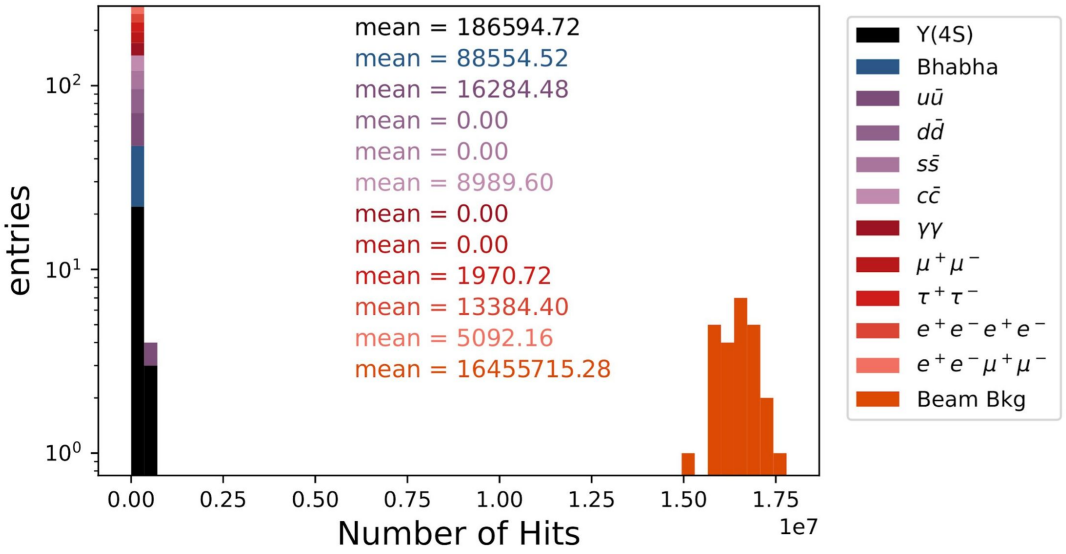
Typical overlap, visualized



Background pileup

Now with **beam backgrounds**

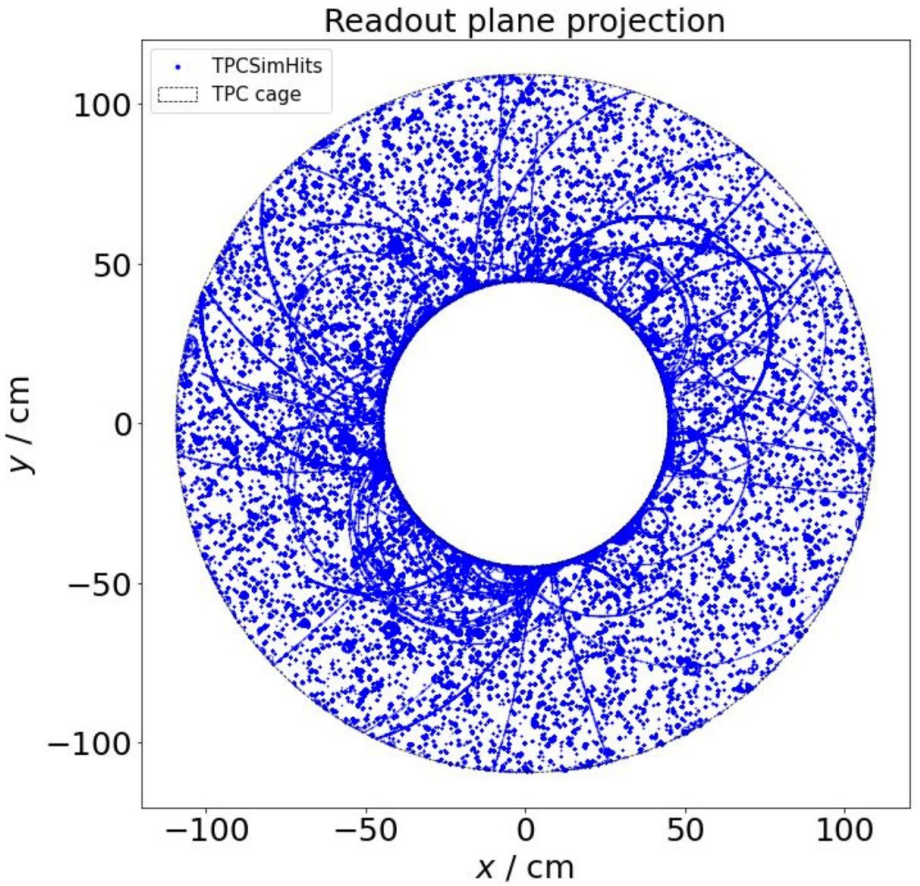
- The hit rate/ionization rate is **dominated** by beam backgrounds...



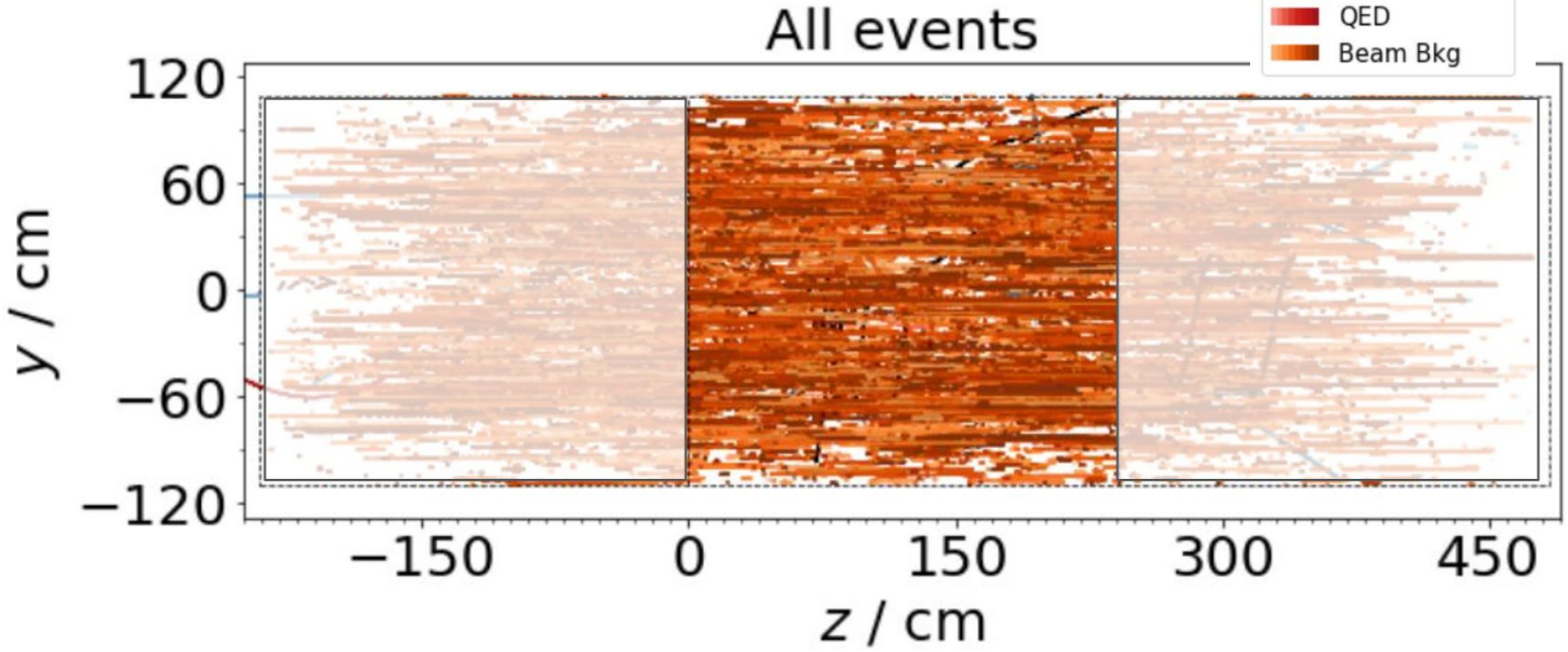
Background pileup

Now with **beam backgrounds**

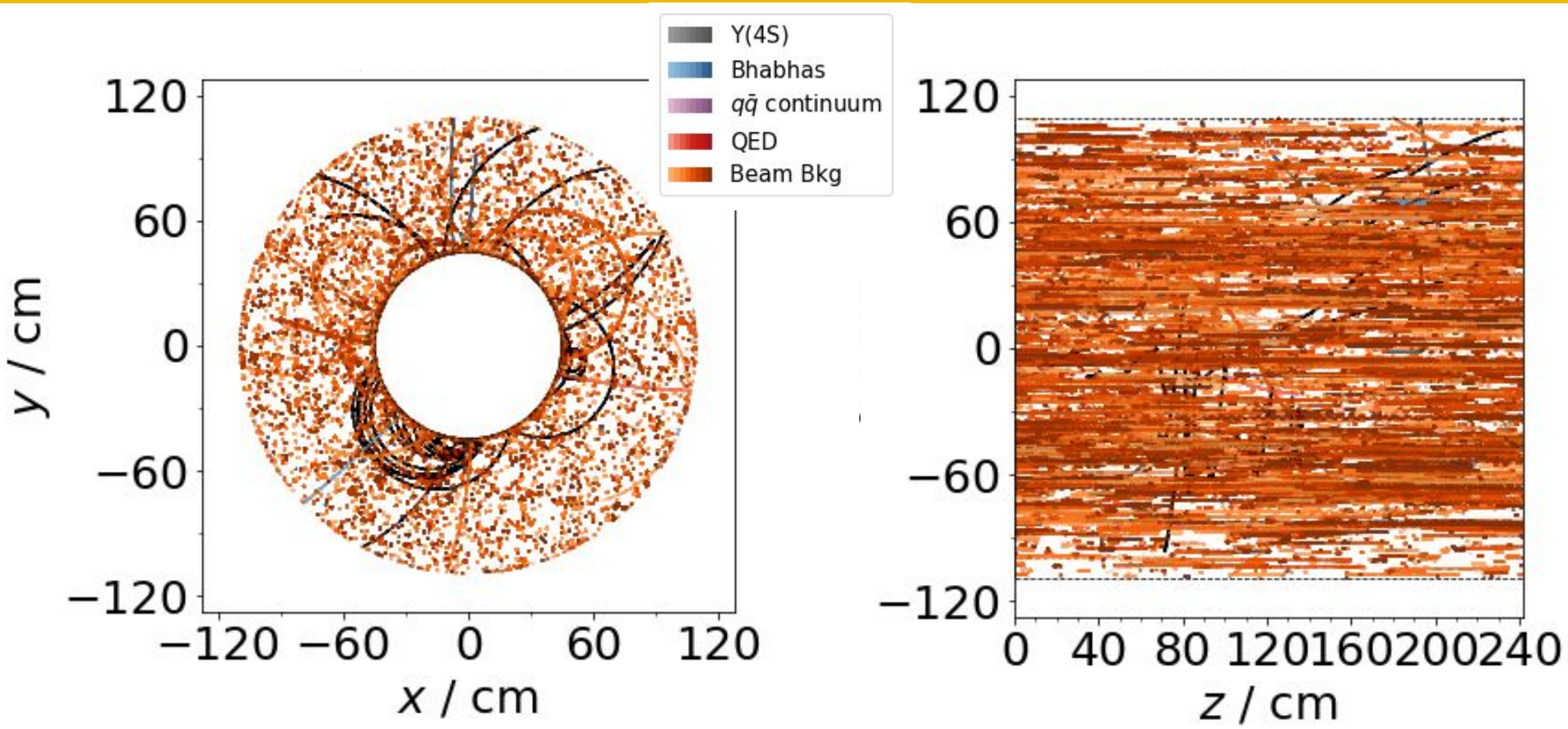
- The hit rate/ionization rate is **dominated** by beam backgrounds…
- These lead to **low-energy microcurlers**
  - Responsible for **huge majority of total ionization**
  - Evaluating multiple ways to suppress (from chip trigger masks and FPGA algorithms through tracking filters)
  - LCTPC has shown excellent rejection of these kinds of hits: we should too
  - ***But*** this will still lead to high **ion backflows**



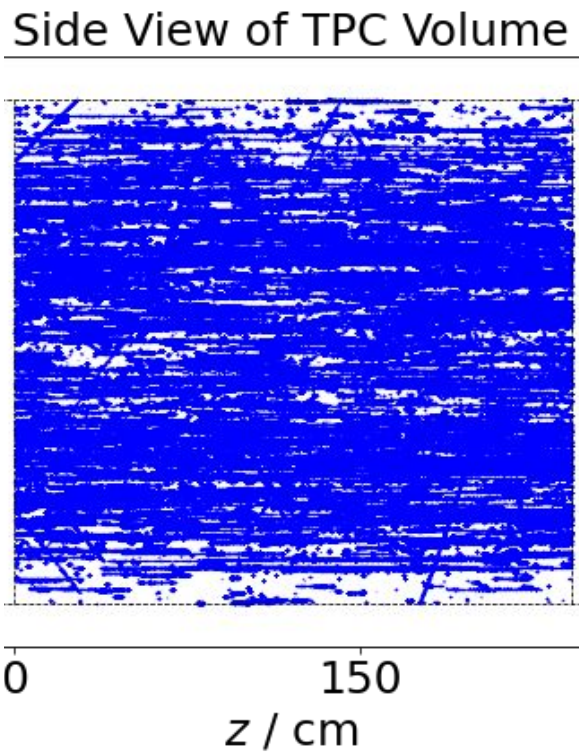
Background pileup



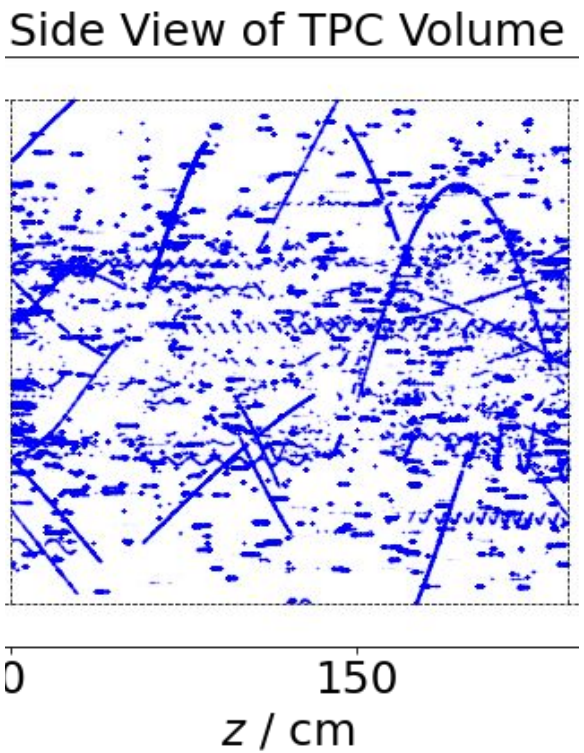
Background pileup



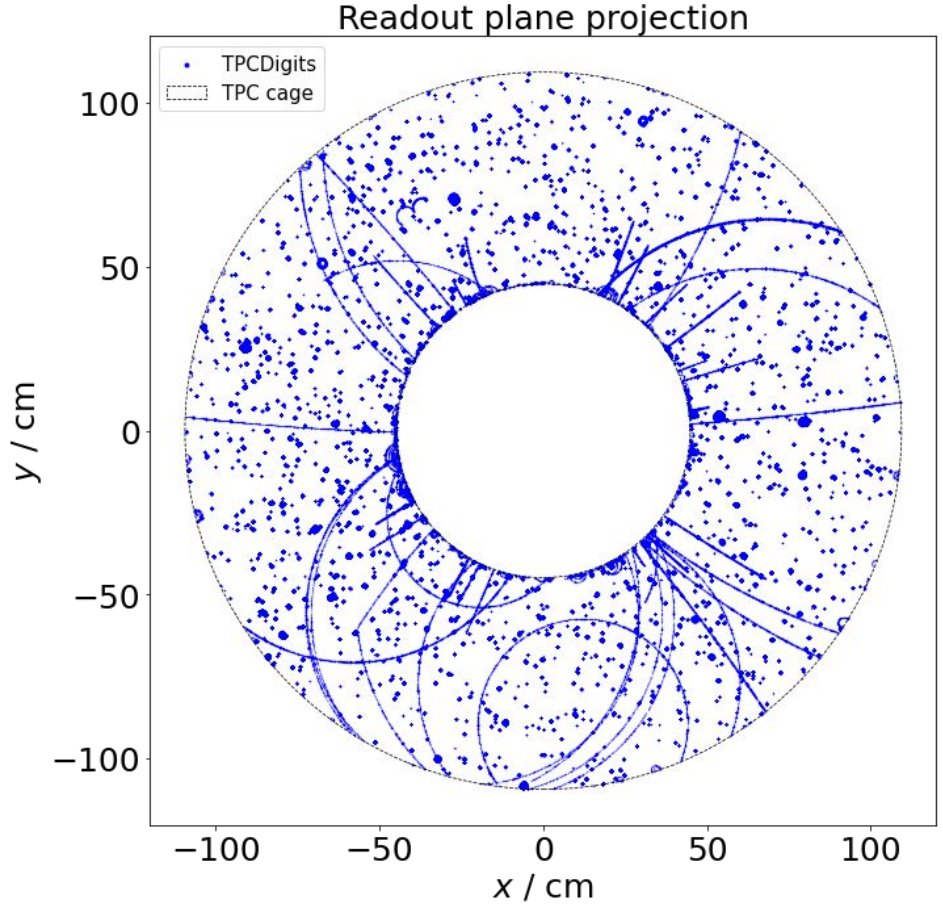
Background rejection

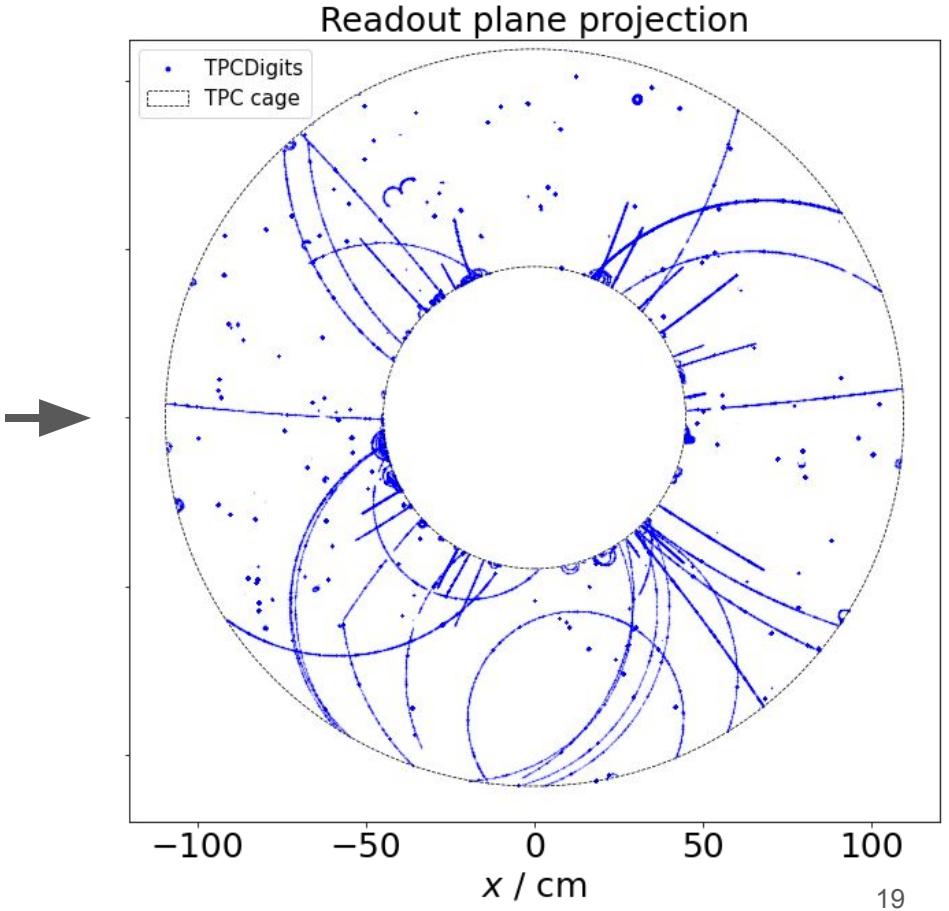


Microcurler removal at whole chip level



Background rejection





The next steps

Evaluate **performance**

- Key tracking variable $\mathbf{p_T}$:
  - Dependence on amplification/readout choice?
  - Dependence on background rates?
  - Effect of ion backflow?
  - Effect of diffusion?
- Particle identification via dE/dx

The next steps

Evaluate **multiple TPC scenarios**

- Replace pixels with pads/strips, something else?
  - Cost
  - Unnecessary resolution (?)
- Ion backflow suppression:
  - GEM stack (low backflow, higher data throughput)
  - Partial or adaptive gating (?)
- Potential alternative gases (for v_d, ion mobility, etc.)

Our *goal* for the white paper is to evaluate several possible scenarios, at least one of which will (hopefully) meet Belle II+ tracking requirements